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Title: Transition to Mission Applications

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Transition to Mission Applications

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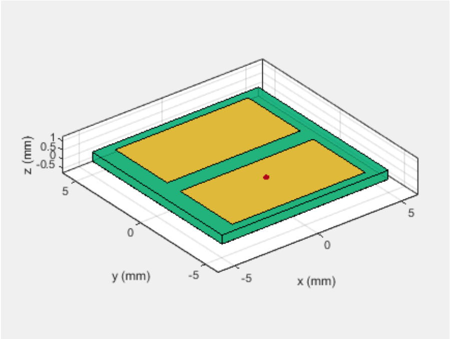
Transition to Mission Applications

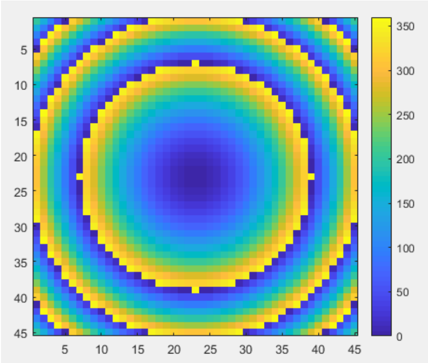
Objective: Transition emerging phased-array metamaterial DR research to sensing, imaging, and communications applications.

- System-level model-based analysis tools
  - MATLAB/Simulink
    - Adds multi-Phenomenology analysis and systems prototyping
      - Orbital dynamics, aperture correction and calibration, controls, communications, …
    - Industry standard software, Integrates with Agile and Cognitive Space Tools
- Manage security firewall
  - Forward feedthrough and reverse feedback between R&D team and application
- Develop customer base through Program Office

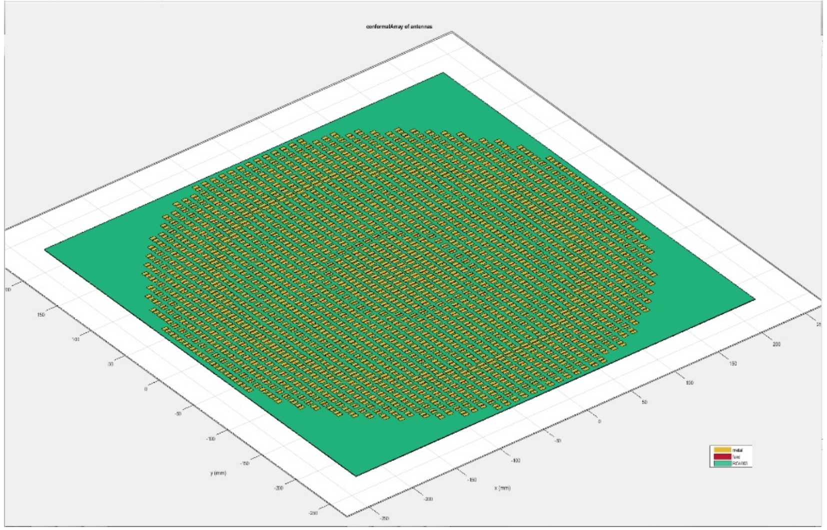
Several Model-Based Paths Identified



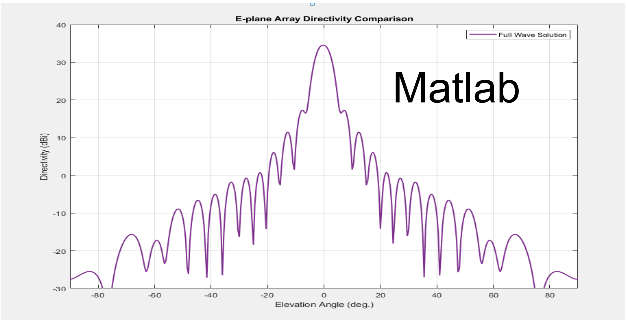
Generate elements

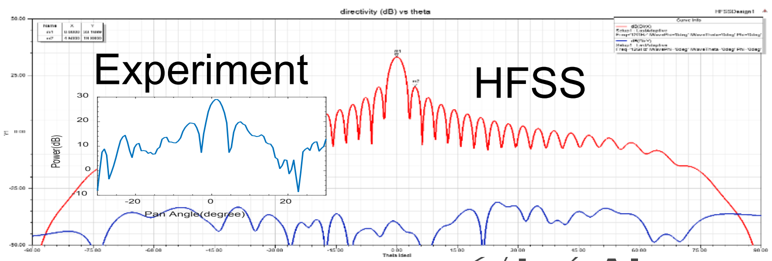


Generate phase map
(& design files)



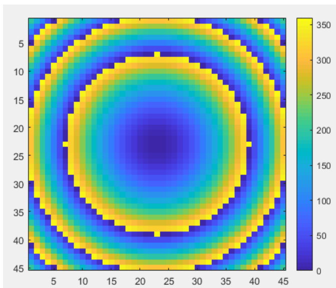
Generate system model



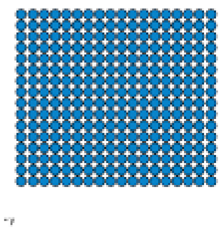


Application-Specific Systems Analysis

This tool is built with an eye toward integration (e.g. DSP, comms, electronics)

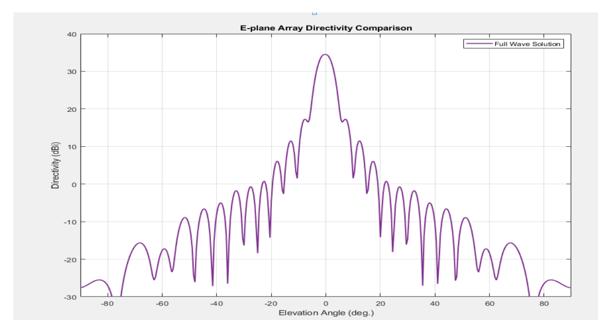


Phase map



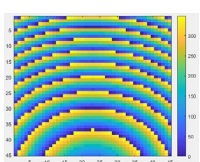
Generate array

System Interaction



Acquire antenna characteristics

Algorithmic feedback (optional)



Generate new phase map
(e.g. for steering, correction, etc)

The Competition – How do metasurface arrays compare ?

http://www.microwavejournal.com/articles/28592-anokiwave-ball-aerospace-enable-future-of-wireless-with-phased-array-antenna-innovator-kits

The AWMF-0129 is a 64-element, single polarization 5G phased array antenna designed to cover the 27.5-30 GHz frequency band. It is a planar antenna that can be used either as a stand-alone component, or combined and synchronized with other arrays to support hybrid beamforming and MIMO functionality as part of larger array. With 50 dBmi of EIRP, the array supports multiple beam widths. A wide beam is available to support channel state information measurements, search modes and broadcast channels. Multiple progressively narrower beams can be used for beam acquisition. The narrowest beams allow for interference mitigation, optimizing SNR, maximizing EIRP, and range extension. A two-dimensional scan volume of $\pm$60 degrees in both azimuth and elevation is supported.

http://www.microwavejournal.com/authors/3629-anokiwave-inc-san-diego-calif

Performance Comparisons

MxN Phase Array Parameters	Conventional	Metasurface
LNA	*MxN*	*1*
Phase Shifter	*MxN*	*MxN*
Power Amplifier	*MxN*	*1*
Interconnects	*MxN*	*M+N*, Row/Column
Phase Shifting: Range/Linearity	Good/Linear	> 2π, Correctable Nonlinearities
Bandwidth	Good	Good > 30%
Multi-Beam	Yes	Yes
Efficiency (Loss)	Good	Unknown
Deployable	Difficult	Yes
Polarization	Linear/Circular	Linear/Circular
Spatial Scan Rate	Very Fast	Slow to Moderate Speeds <10ms
Linear-Scalable SWaP	No - Quadratic	Yes
Array Size	Limited by SWaP Scaling	Large >1000
Reliability	Very Good – Gradual Degradation	Potential for Single Point Failure

Green = Good Performance, Red = Poor Performance, Blue = TBD

Summary and Path Forward

- Continued development of model-based tools
  - Implement dynamic single-cell metasurface model
- Security Firewall: Science <> Application
  - Successful execution of the DR will not only advance the science and application of metasurfaces, but also provide a template for future collaborations across LANL *to advance new discoveries in fundamental science to applied solutions to address national security challenges*
- Deployment
  - Mechanical
  - Phase correction

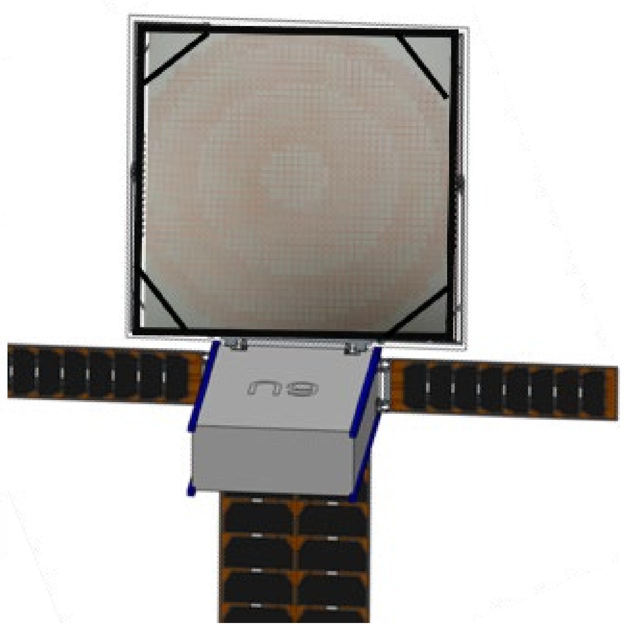
Deployment - Mechanical Concept

The key considerations for SmallSat antennas:

- Ability to stow in a small form factor
- Easy and reliable deployment

Deployable methods:

- Mechanical hinge
- Inflatable balloon

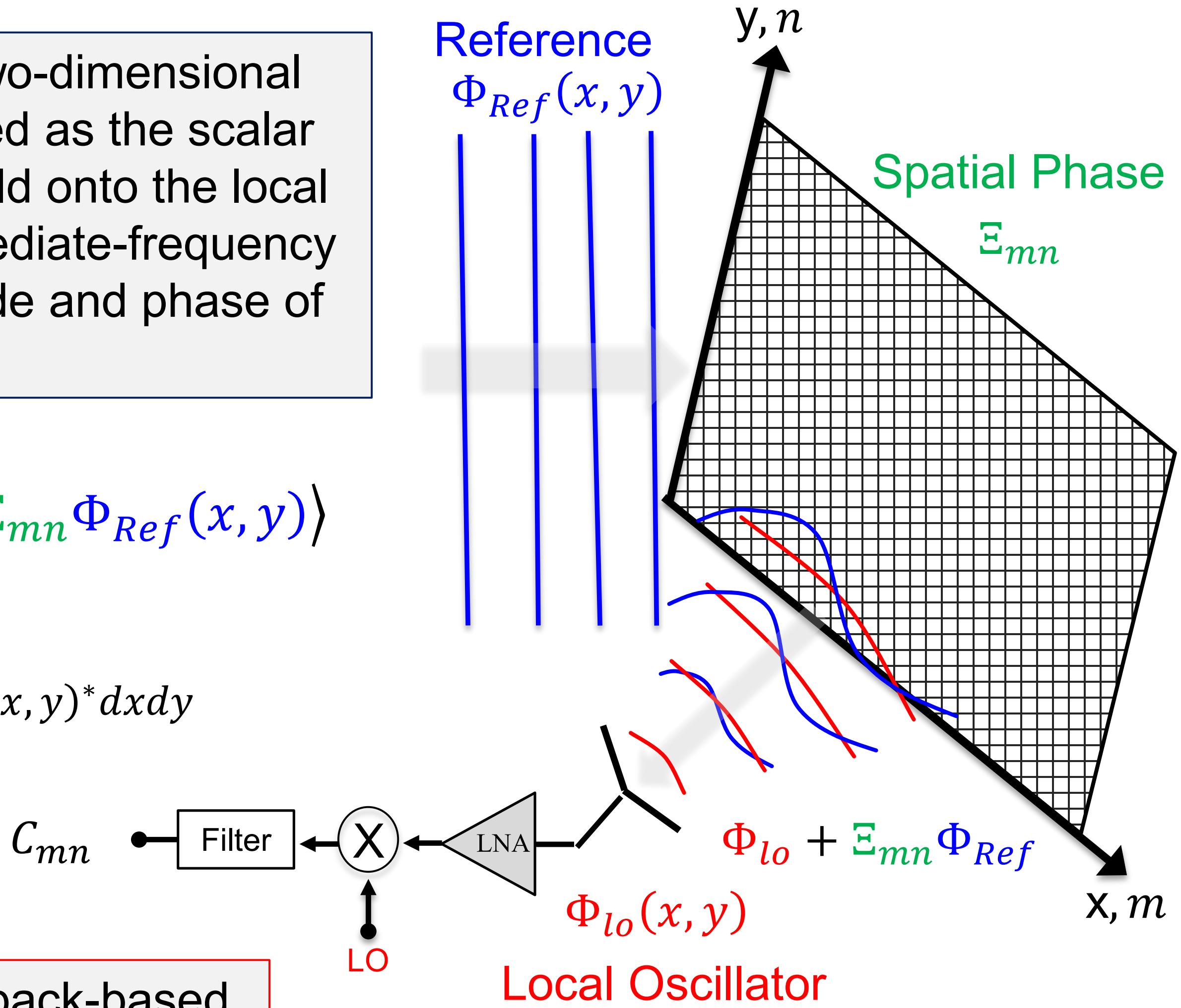


Phase Correction – Scalar Projection

The coherent detection of two-dimensional spatial fields can be perceived as the scalar projection of the reference field onto the local oscillator field with the intermediate-frequency signal conveying the amplitude and phase of the projection.

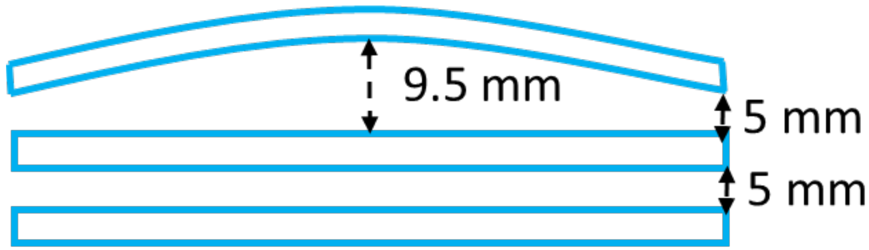
$$C_{mn} = \alpha e^{-i\beta} = \left\langle \Phi_{lo}(x,y), \Xi_{mn}\Phi_{Ref}(x,y) \right\rangle$$

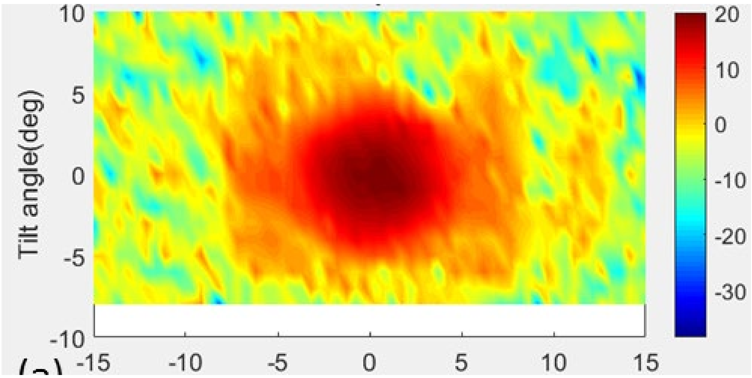
$$\langle U(x,y)V(x,y)\rangle \equiv \iint_{x_1,y_1}^{x_2,y_2} U(x,y)V(x,y)^* dxdy$$



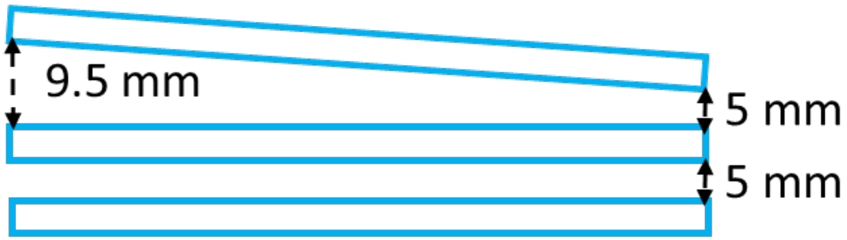
Development of feedback-based phase-correction algorithms.

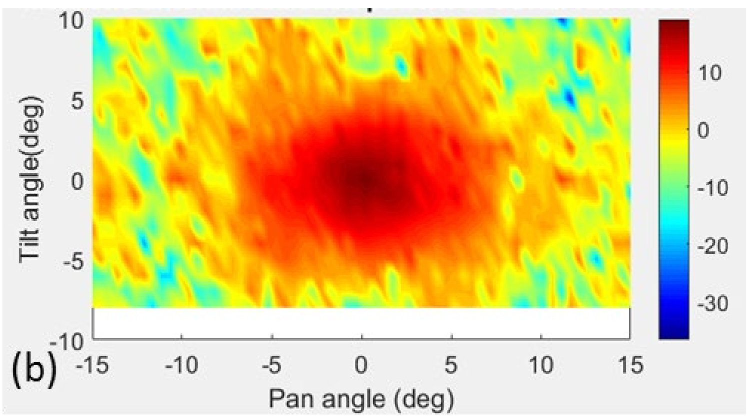
Backup - Uneven Layer Separation





- ➢ Observed a deviation of main lobe from circular to elliptical
- ➢ Gain of the main lobe reduced by ~ 5 dB





- ➢ Observed a deviation of main lobe from circular to elliptical
- ➢ Gain reduction is higher than a centered perturbation